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**CHEMISTRY**

**UNIT 1 & 2**

**2020**

**MARKING GUIDE**

**Section One: Multiple-choice (25 marks)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | a □ b □ c □ d ■ |  | 11 | a □ b □ c □ d ■ |  | 21 | a □ b ■ c □ d □ |
| 2 | a □ b ■ c □ d □ |  | 12 | a □ b □ c ■ d □ |  | 22 | a □ b ■ c □ d □ |
| 3 | a ■ b □ c □ d □ |  | 13 | a □ b □ c ■ d □ |  | 23 | a □ b ■ c □ d □ |
| 4 | a □ b ■ c □ d □ |  | 14 | a ■ b □ c □ d □ |  | 24 | a □ b □ c ■ d □ |
| 5 | a □ b ■ c □ d □ |  | 15 | a □ b □ c ■ d □ |  | 25 | a □ b □ c □ d ■ |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 6 | a □ b □ c □ d ■ |  | 16 | a ■ b □ c □ d □ |  |  |  |
| 7 | a □ b □ c ■ d □ |  | 17 | a □ b □ c ■ d □ |  |  |  |
| 8 | a ■ b □ c □ d □ |  | 18 | a ■ b □ c □ d □ |  |  | (1 mark per question) |
| 9 | a □ b □ c ■ d □ |  | 19 | a □ b □ c □ d ■ |  |  |  |
| 10 | a □ b □ c ■ d □ |  | 20 | a □ b □ c □ d ■ |  |  |  |

**Section Two: Short answer 35% (83 marks)**

This section has **10** questions. Answer **all** questions. Write your answers in the spaces provided.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 65 minutes.

**Question 26 (12 marks)**

Consider the information given in the table below.

|  |  |  |  |
| --- | --- | --- | --- |
| **Name of compound** | **Formula** | **Molar mass (g mol-1)** | **Melting point (°C)** |
| hydrogen peroxide | H2O2 | 34.016 | -0.43 |
| fluoromethane | CH3F | 34.034 | -137.8 |
| chromium(III) chloride | CrCl3 | 158.35 | 1152 |
| magnesium sulfate | MgSO4 | 120.38 | 1124 |
| dichlorine hexoxide | Cl2O6 | 166.9 | 3.5 |

(a) Explain, in terms of structure and bonding, why the melting points of magnesium sulfate and chromium(III) chloride are so high, compared to the other compounds. (4 marks)

* **MgSO4 and CrCl3 are ionic compounds / contain ionic bonds**
* **There is a strong electrostatic attraction between cations and anions**
* **Therefore a large amount of heat is required to disrupt the bonds in the ionic compounds (resulting in high melting points)**
* **The other substances are covalent molecular and have only weak intermolecular forces**

(b) Explain, in terms of structure and bonding, the difference between the melting points of hydrogen peroxide and fluoromethane. (4 marks)

* **Both substances have similar molecular masses and therefore similar strength dispersion forces**
* **CH3F has dipole-dipole (in addition to its dispersion forces)**
* **H2O2 has dipole-dipole and hydrogen bonding (in addition to its dispersion forces)**
* **Therefore H2O2 has the stongest total intermolecular forces and highest boiling point**

If 100 g of magnesium sulfate and 100 g of chromium(III) chloride were placed in separate beakers and dissolved in equal volumes of distilled water;

(c) Determine, with the use of calculations, which solution would have the higher electrical conductivity. (4 marks)

* **n(MgSO4) = m/M**

**= 100 / 120.38**

**= 0.8307 mol**

**n(CrCl3) = m/M**

**= 100 / 158.35**

**= 0.6315 mol**

* **n(total ions in MgSO4) = 2 x 0.8307**

**= 1.6614 mol**

* **n(total ions in CrCl3) = 4 x 0.6315**

**= 2.526 mol**

* **Since CrCl3 has the greater total number of dissociated ions (mobile charge), it will have the highest conductivity**

**Question 27 (6 marks)**

The graph below shows separate trendlines (labelled A, B and C) relating to some of the physical properties displayed by the elements in period 3. The lines represent the trends in ionisation energy, atomic radius and electronegativity.

**C**

**B**

**A**

State which line corresponds to each trend. Justify your choices.

|  |  |
| --- | --- |
|  | A, B or C |
| ionisation energy | **C** |
| atomic radius | **B** |
| electronegativity | **A** |

**(1m for correctly allocating A, B and C)**

* **Atomic radius decreases across a period (and line B is the only decresing trend)**
* **This is due to increased positive charge within the nucleus, pulling valence electrons closer**
* **Electronegativity increases across a period, due to the increased positive charge from the nucleus exerting a stronger pull on (a bonding pair of) electrons**
* **However there is no value given for Argon (noble gas, octet arrangement, not allocated an electronegativity value) therefore electronegativity must be line A**
* **Ionisation energy increases across a period, as the energy required to remove an electron from an atom increases, therefore line C**

**Question 28 (8 marks)**

Consider the reaction between calcium carbonate powder and **excess** 1 mol L-1 nitric acid.

(a) List three (3) aqueous species that would be present in the test tube upon completion of this reaction. (3 marks)

* **Ca2+(aq)**
* **NO3-(aq)**
* **H+(aq) / H3O+(aq)**

**accept also CO2(aq) and H2CO3(aq)**

**(HCO3-, CO32- and OH- negligible in a solution with excess nitric acid)**

**\* if more than 3 species listed, mark only the first 3 answers given**

Consider two (2) test tubes; one containing 0.5 mol L-1 NaOH(aq) and one containing 0.5 mol L-1 Ba(OH)2(aq). A few drops of sulfuric acid was added to each test tube.

(b) Describe how the subsequent observations would allow you to distinguish these two solutions. (3 marks)

* **A white precipitate would form in one test tube**
* **This would therefore allow identification of the Ba(OH)2 solution, as BaSO4(s) is formed**
* **The remaining test tube with no visible change (colourless solution remaining) would be NaOH solution**

A piece of freshly polished aluminium metal was placed into a beaker containing 1 mol L-1 hydrochloric acid.

(c) Write a balanced ionic equation for the reaction that would occur. (2 marks)

|  |
| --- |
| **2 Al(s) + 6 H+(aq) → 2 Al3+(aq) + 3 H2(g)**  **(1m correct reactant and product species, 1m correct balancing)** |

**Question 29 (8 marks)**

Consider the two (2) gas chromatograms below. Both analyses, A and B, were performed on identical gas samples. All chromatography conditions were controlled, except the temperature of the gas chromatograph oven was different in each case.

**Chromatogram A Chromatogram B**

Absorbance

Retention time (mins)

l l l l

5 10 15 20

Absorbance

Retention time (mins)

l l l l

5 10 15 20

(a) Name an appropriate gas which could have been used as the mobile phase. (1 mark)

* **Any of helium, nitrogen, hydrogen, argon**

(b) Which gas chromatogram (A or B) was performed at the higher temperature? Justify your answer. (3 marks)

* **Chromatogram A**
* **A higher temperature means particles will have a greater average kinetic energy**
* **Therefore they will move through the column faster, resulting in a lower retention time**

When a sample of gas is cooled, the resultant effect on gas volume can be illustrated by the graph below.

Temperature (°C)

Volume (L)

l

-273.15 °C

(c) Why can’t the sample be cooled any lower than -273.15 °C? (2 marks)

* **This temperature is absolute zero**
* **Sample cannot be cooled any lower because; (any one of following justifications)**
  + - * **this is the lowest temperature possible**
      * **all particle motion stops at this temperature**
      * **the volume of the gas particles would have to be negative which is impossible**

An ideal gas has a theoretical volume of zero at the temperature of -273.15 °C.

(d) Explain how the behaviour of a real gas differs from this. (2 marks)

**(any two of the following points)**

* **The particles of an ideal gas have no volume themselves, allowing the ideal gas volume to be zero**
* **However the particles of a real gas do occupy volume, meaning the volume can never be zero**
* **A real gas would condense and then solidify as it approaches this temperature**

**Question 30 (7 marks)**

Consider the diagrams below, which show two (2) different representations of atoms of the same neutral element.

**Configuration A Configuration B**

**+**

e-

e-

e-

e-

e- e-

e- e-

e-

e-

e-

**+**

e-

e-

e- e-

e-

e-

e- e-

e-

e-

e-

e- = electron

(a) Which configuration (A or B) represents the element is its ground state? Justify your answer. (2 marks)

* **B**
* **All electrons are filling the shells from lowest to highest / inner shell to outer shell (Configuration A is 2, 6, 2, 1 whilst Configuration B is 2, 8, 1)**

(b) Which transition would result in the release of a characteristic colour during a flame test? Circle your choice and justify your answer.

(3 marks)

A to B OR B to A

* **(circle A to B)**
* **Energy is released as electrons move from higher to lower energy shells**
* **This energy can be in the form of a photon of coloured light / This energy corresponds with a particular frequency in the electromagnetic spectrum**

(c) Which element is represented in these diagrams? (1 mark)

* **Sodium, Na**

(d) Write the electron configuration of the element in Group 15, that is in the same period as the element represented above. (1 mark)

* **(Phosphorus) 2, 8, 5**

**Question 31 (8 marks)**

Consider the information given in the table below, regarding substances A, B and C.

|  |  |  |  |
| --- | --- | --- | --- |
| **Substance** | **Conductivity**  **as a solid** | **Conductivity**  **as a liquid** | **Melting point (°C)** |
| A | No | No | 1895 |
| B | Yes | Yes | 812 |
| C | No | Yes | 1133 |

(a) Which substance (A, B or C) is likely to be covalent network? Justify your answer in terms of structure and bonding. (3 marks)

* **A**
* **No conductivity in the solid or liquid state indicates no mobile charge**
* **Very migh melting point indicates strong bonds present which would require a large amount of energy to disrupt**

(b) Which substance (A, B or C) is likely to be malleable? Justify your answer in terms of structure and bonding. (5 marks)

* **B**
* **Conductivity as a solid (and liquid) suggests metallic bonding is present**
* **Metallic bonding consists of non-directional bonds between delocalised electrons and positive metal ions**
* **When a force is applied the substance can change shape without disrupting / breaking the bonds**
* **Therefore metals are malleable**

**Question 32 (9 marks)**

The precipitation reaction between copper(II) nitrate solution and aqueous sodium sulfide can be represented by the chemical equation below.

Cu(NO3)2(aq) + Na2S(aq) → CuS(s) + 2 NaNO3(aq)

(a) Write observations for this reaction. (3 marks)

* **Blue and colourless solutions are mixed**
* **A black solid forms**
* **The blue solution fades to colourless**

An investigation was to be performed, using this reaction. Students decided to test how the concentration of Cu(NO3)2(aq) affected the rate of reaction.

(b) Suggest how the rate of this reaction could be easily measured. Your answer should include a brief description of the method used to measure the reaction rate. (3 marks)

* **Place the glass reaction vessel over a visible cross / mark**
* **Use a stopwatch to measure the time taken**
* **For the black precipitate to obscure the cross / mark**

(c) Is this reaction likely to have a low or high activation energy? Justify your answer with reference to the chemical bonds in the reactants. (3 marks)

* **Low**
* **This reaction doesn’t require the breaking of any bonds in the reactants**
* **The ions are already dissociated and can collide easily and react with little energy input (OR there is instantaneous electrostatic attraction between oppositely charged aqueous ions)**

**Question 33 (8 marks)**

Dry ice is solid carbon dioxide. Under atmospheric pressure, it can only form at a temperature below -78.5 °C. It is used for transporting fresh meat, poultry, fish and pre-made meals. At temperatures above -78.5 °C, dry ice undergoes sublimation, which means it converts directly from a solid to a gas.

(a) State whether the process of sublimation is endothermic or exothermic. Justify your answer, including a discussion of the movement of heat between system and surroundings. (4 marks)

* **Endothermic**
* **Sublimation requires the disruption of intermolecular forces**
* **Heat must move from the the surroundings into the system**
* **This results in a temperature decrease / This results in a positive DH value**

(b) Write a chemical equation, including state symbols, representing the sublimation of carbon dioxide. Your equation should incorporate information regarding the associated enthalpy change. (2 marks)

|  |
| --- |
| **CO2(s) + heat → CO2(g)**  **(1m reactants and products, 1m heat)** |

Dry ice can be purchased as small pellets or larger blocks.

(c) If a single pellet of dry ice had a mass of 1.22 g, calculate the number of carbon dioxide molecules this pellet would contain. (2 marks)

**n(CO2) = m / M**

**= 1.22 / 44.01**

**= 0.027721 mol**

**N(CO2) = n x Av**

**= 0.027721 x 6.022 x 1023**

**= 1.669 x 1022**

**= 1.67 x 1022 (3 SF)**

**Question 34 (10 marks)**

The indicator ‘bromothymol blue’ has the formula C27H28Br2O5S. The diagram below illustrates the different colours exhibited by bromothymol blue at various pH levels.

-1 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14

pH

|  |  |  |  |
| --- | --- | --- | --- |
|  | magenta | yellow | blue |

(a) State the type of bonding (metallic, ionic or covalent) present in bromothymol blue. Justify your answer. (2 marks)

* **Covalent**
* **All non-metal elements in the chemical formula**

(b) Calculate the percentage by mass of carbon in bromothymol blue. (2 marks)

**% C = 27 x 12.01 x 100 = 324.27 x 100**

**624.364 624.364**

**= 51.94 %**

(c) Explain why, when a few drops of bromothymol blue are added, a 1 mol L-1 solution of HCl(aq) is magenta, but a 1 mol L-1 solution of CH3COOH(aq) is yellow. Support your answer with relevant chemical equations. (6 marks)

* **HCl is a strong acid whereas CH3COOH is a weak acid**
* **This means HCl is completely ionised whereas CH3COOH is only partially ionised**
* **HCl(aq) → H+(aq) + Cl-(aq)**
* **CH3COOH(aq) ⇌ CH3COO-(aq) + H+(aq)**
* **Therefore HCl has a greater concentration of H+ resulting in a lower pH / resulting in a pH below 1**

**OR**

* **Therefore CH3COOH has a lower concentration of H+ resulting in a higher pH / resulting in a pH above 1**
* **This results in HCl appearing magenta whilst CH3COOH appears yellow**

**Question 35 (7 marks)**

Consider the organic compound below.



(a) Give the IUPAC name for this compound. (1 mark)

* **2-chlorobutane**

(b) Name the reactants that you would mix together to produce this compound by; (4 marks)

|  |  |
| --- | --- |
| An addition reaction. | **Hydrogen chloride / hydrochloric acid (1)**  **But-1-ene / But-2-ene (1)** |
| A substitution reaction. | **Chlorine (1)**  **Butane (1)** |

(c) Which of the reaction types in part (b) would require the presence of a catalyst? Name the catalyst. (2 marks)

* **Substitution reaction**
* **UV light**

End of Section Two

**Section Three: Extended answer 40% (102 marks)**

This section contains **five (5)** questions. You must answer **all** questions. Write your answers in the spaces provided below.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to the appropriate number of significant figures.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 75 minutes.

**Question 36 (14 marks)**

Analysis of various hair products such as dyes, sprays and serums can be of great benefit to forensic investigators. Since hair samples are often found at crime scenes, identification of the hair products which are coating the hair can provide valuable information to investigators.

One common and effective method used for the analysis of hair products is thin layer chromatography (TLC). The TLC plate below shows the analysis of six (6) different popular brands of hair spray.

12

11

10

9

8

7

6

5

4

3

2

1

0 cm

X X X X X X

*solvent front*

*sample*

*line*

Hair Pump up Intensive Let’s get Hairytale Style

raising the volume hair frizzy ending it up

A

B

W

X

Y

Z

The plate, which is the stationary phase, is made of glass coated with silica. A small amount of each hair spray was spotted onto the sample line. The plate was then placed into a solution which acted as the mobile phase.

(a) Briefly describe how the technique of TLC is able to separate the various components of a sample. Your answer should make reference to the role of both the stationary and mobile phases. (4 marks)

* **Mobile phase moves upwards across stationary phase, carrying components of sample with it**
* **Components interact to varying degrees with stationary and mobile phases based on their polarity**
* **Components that adhere more strongly to the stationary phase move more slowly, whilst those dissolving to a greater degree in the mobile phase move more quickly**
* **Components therefore move at different rates up the plate and are thus separated**

For the TLC plate shown on the previous page, the scientists found that using a mobile phase composed of tetrachloromethane and cyclohexane (mixed in a 90:10 ratio) achieved optimal separation of components.

(b) Draw full structural diagrams for the two (2) substances used in the mobile phase. Your diagrams should indicate all bonds and atoms. (2 marks)

|  |  |
| --- | --- |
| tetrachloromethane | cyclohexane |
|  |  |

(c) State whether this mobile phase is polar or non-polar. Justify your answer. (2 marks)

* **Non-polar**
* **Both substances are symmetrical / Both have even charge distribution / Neither substance has a net dipole**

Consider components A and B, which are labelled on the TLC plate, as well as the other information provided regarding the stationary and mobile phases.

(d) Which component, A or B, is likely to be the most polar? Justify your answer. (3 marks)

* **B**
* **(Since the mobile phase is non-polar) the non-polar components will be more soluble in the mobile phase and move upwards more quickly**
* **Polar components will therefore move more slowly up the plate**

A hair sample from a crime scene was analysed by TLC and found to be coated in the hairspray ‘Style it up’.

(e) Calculate the retention factor (Rf) values for each of the components (labelled W, X, Y and Z on the TLC plate) found in the hairspray ‘Style it up’. (2 marks)

Rf = distance travelled by component

distance travelled by solvent

|  |  |
| --- | --- |
|  | Rf |
| W | **accept between 0.68 - 0.71** |
| X | **accept between 0.51 - 0.53** |
| Y | **accept between 0.42 - 0.45** |
| Z | **accept between 0.20 - 0.22** |

**(-1m per error)**

Hair samples were then taken from three (3) suspects who had been arrested. The coatings on their hair samples were analysed by TLC. You may assume this analysis was performed under conditions identical to the original plate.

Based on the data provided by these TLC analyses;

(f) Which suspect is most likely to have been at the scene of the crime? (1 mark)

* **Mrs Peacock**

**Question 37 (22 marks)**

The silver-coloured metal molybdenum was first isolated in 1781. Molybdenum does not exist as the free metal, but is commonly found combined with sulfur, in the compound molybdenite, MoS2.

The overall equation for the extraction of molybdenum from molybdenite is as follows.

2 MoS2(s) + 7 O2(g) + 6 H2(g) → 2 Mo(s) + 4 SO2(g) + 6 H2O(l)

A batch of ore containing 57.4% (by mass) MoS2(s) was placed in a reaction chamber. Oxygen and hydrogen gases were then pumped into the chamber.

The oxygen gas used in this process is extracted from air, which is comprised of 21.0% (by volume) O2(g). If 3.50 x 107 L of air, stored at STP, was available for this extraction process;

(a) Calculate the maximum mass of ore that would have been able to react with the available oxygen. (5 marks)

**V(O2) = 21 / 100 x 3.5 x 107**

**= 7 350 000 L**

**n(O2) = V / 22.71**

**= 7 350 000 / 22.71**

**= 323 645.97 mol**

**n(MoS2) = 2 / 7 x n(O2)**

**= 2 / 7 x 323 645.97**

**= 92 470.28 mol**

**m(MoS2) = nM**

**= 92 470.28 x 160.08**

**= 14 802 642 g**

**m(ore) = 14 802 642 x 100 / 57.4**

**= 25 788 575 g**

**= 2.58 x 107 g OR 25.8 t (3 SF)**

The hydrogen gas used in the extraction of molybdenum is produced by a series of reactions that can be summarised by the following equation;

CH4(g) + 2 H2O(g) → 4 H2(g) + CO2(g)

(b) Calculate the volume of methane at STP, that would be required to produce enough H2(g) for this extraction process. (3 marks)

**n(H2 required) = 6 / 7 x n(O2)**

**= 6 / 7 x 323 645.97**

**= 277 410.832 mol**

**n(CH4 required) = 1 / 4 x n(H2)**

**= 1 / 4 x 277 410.832**

**= 69 352.708 mol**

**V(CH4) = 22.71n**

**= 22.71 x 69 352.708**

**= 1 575 000 L**

**= 1.58 x 106 L OR 1.58 ML (3 SF)**

**\* award follow through marks for using incorrect n(O2) from part (a)**

The SO2(g) produced during the extraction of molybdenum is a pollutant and can contribute to the formation of acid rain. Sulfur dioxide gas dissolves into the water in the atmosphere to produce sulfurous acid.

(c) Write an equation representing this reaction. (1 mark)

|  |
| --- |
| **SO2(g) + H2O(l) → H2SO3(aq)** |

The sulfurous acid produced is a weak, diprotic acid.

(d) Define each of these terms, as used in this context. (2 marks)

|  |  |
| --- | --- |
| weak | **Only a proportion of the acid molecules ionise in water /**  **Low degree of ionisation in water** |
| diprotic | **Two ionisable hydrogen atoms per molecule /**  **Two acidic hydrogen atoms per molecule /**  **Can produce two moles of H+ per one mole of acid** |

(e) State and explain the resulting effect on pH, which is caused by the dissolving of SO2(g) into rain. Use a chemical equation to support your answer. (3 marks)

* **H2SO3(aq) ⇌ H+(aq) + HSO3-(aq)**
* **The increase in H+ concentration lowers the pH**
* **Since pH = -log [H+]**

If the waste sulfur dioxide is collected, it can be converted into sulfuric acid in an industrial procedure known as the Contact process. This process can be summarised by the equation below.

2 SO2(g) + O2(g) + 2 H2O(l) → 2 H2SO4(aq)

This process can produce sulfuric acid with a very high concentration of 16.9 mol L1-.

(f) Calculate the volume of H2SO4(aq) that could be produced using the waste sulfur dioxide generated by the extraction of molybdenum from this batch of ore. (3 marks)

**n(SO2) = 4 / 7 x n(O2)**

**= 4 / 7 x 323 645.97**

**= 184 940.55 mol**

**n(H2SO4) = n(SO2)**

**= 184 940.55 mol**

**V(H2SO4) = n / c**

**= 184 940.55 / 16.9**

**= 10 943.23 L**

**= 1.09 x 104 L OR 10.9 kL (3 SF)**

**\* award follow through marks for using incorrect n(O2) from part (a)**

A sample of pure molybdenum was analysed by mass spectrometry and the following data was obtained.

(g) Use this information, as well as that in your Data Booklet, to complete the following table about the element molybdenum. (3 marks)

|  |  |
| --- | --- |
| Group number | **6** |
| Period number | **5** |
| Number of isotopes | **7** |

(h) Describe, with reference to subatomic particles, the similarities and differences between the isotopes of molybdenum. (2 marks)

* **All isotopes have the same number of protons (always 42)**
* **Each isotope has a different number of neutrons (either 50, 52-56, 58)**

**Question 38 (25 marks)**

The Perth Desalination Plant in Kwinana supplies approximately 17% of Perth’s potable (drinkable) water.

The two (2) main sources of potable water in Perth, are groundwater and seawater.

(a) Define the term ‘desalination’ and state which of these 2 main water sources would be processed at the desalination plant. (2 marks)

* **Removal of salt from water**
* **Seawater**

The desalination plant at Kwinana operates 24 hours a day. It produces 6000 m3 of drinking water every hour. If 1 m3 = 1000 L of water;

(b) Calculate how many litres of drinking water are produced by the desalination plant each day. (2 marks)

**V(water) = 6000 x 1000 x 24**

**= 144 000 000 L per day**

**= 144 x 106 L per day OR 1.44 x 108 L per day**

The initial stages of water treatment at the desalination plant involve the processes of filtration and desalination.

(c) Give one (1) reason that the process of filtration would be used. (1 marks)

* **Remove undissolved / insoluble solids**

The filtration and desalination processes produce very ‘clean’ water, however it is not yet suitable for drinking.

As stated previously, the plant produces 6000 m3 of drinking water every hour.

This volume includes the following substances, which are added to the water on an **hourly basis**;

* 180 kg CO2(g)
* 180 m3 Ca(OH)2(aq)
* 6 kg Cl2(g)
* 30 L of 1.512 mol L-1 H2SiF6(aq)

(d) Calculate the volume of CO2(g) that would be required by the desalination plant each day, assuming the gas was stored at STP. (3 marks)

**m(CO2) = 180 x 103 x 24**

**= 4 320 000 g**

**n(CO2) = m / M**

**= 4 320 000 / 44.01**

**= 98 159.51 mol**

**V(CO2) = 22.71n**

**= 22.71 x 98 159.51**

**= 2 229 202 L**

**= 2.2 x 106 L OR 2.2 ML (2 SF)**

The Ca(OH)2(aq) solution used, has a concentration of 1500 ppm and a density of 1.005 g mL-1.

(e) Calculate the concentration of this Ca(OH)2(aq) solution in moles per litre. (5 marks)

**1500 ppm means 1500 mg Ca(OH)2 in 1 kg solution**

**Since r = m/V;**

**V(of 1 kg of solution) = m / r**

**= 1000 / 1.005**

**= 995.025 mL (1)**

**= 0.995 L (1)**

**m(Ca(OH)2 in 1 kg of solution) = 1.5 g (1)**

**n(Ca(OH)2) = m / M**

**= 1.5 / 74.096**

**= 0.020244 mol (1)**

**c(Ca(OH)2) = n / V**

**= 0.020244 / 0.995**

**= 0.020345 mol L-1 (1)**

(f) State the effect on pH when the Ca(OH)2(aq) solution is added to water. Justify your answer. (3 marks)

* **The pH will increase**
* **Ca(OH)2 is a strong base**
* **It will release OH- ions into the solution (lowering the concentration of H+ ions)**

(g) Give one (1) reason for the addition of Cl2(g) to the water. (1 mark)

* **disinfectant**

The fluorosilicic acid, H2SiF6(aq), is added as a source of fluoride, which improves dental hygiene by reducing tooth decay and preventing cavities.

(h) Calculate the final concentration of H2SiF6(aq) in the drinking water. (3 marks)

**n(H2SiF6) = cV**

**= 1.512 x 30**

**= 45.36 mol**

**V(water) = 6000 x 1000**

**= 6 000 000 L**

**c(H2SiF6) = n / V**

**= 45.36 / 6 000 000**

**= 7.56 x 10-6 mol L-1**

All of the fluorine present in H2SiF6(aq) is released into the drinking water as fluoride ions (F-). The final concentration of fluoride ions should be 0.85 mg L-1 ± 2.0% (i.e. an error of 2.0% is allowed).

(i) Calculate the final concentration of F-(aq) present in the drinking water. State, with justification, whether this value falls within the acceptable range of error. (5 marks)

**c(F-) = 6 x c(H2SiF6)**

**= 6 x 7.56 x 10-6**

**= 4.536 x 10-5 mol L-1 (1)**

**i.e. 4.536 x 10-5 mol in 1 L, therefore;**

**m(F-) = nM**

**= 4.536 x 10-5 x 19.00**

**= 8.6184 x 10-4 g (1)**

**= 0.86184 mg (1)**

**2% error range;**

**value needs to be within 0.833 – 0.867 mg L-1 (1)**

**Yes, the concentration is within the acceptable error range (1)**

**\* award follow through marks for using incorrect value from part (h)**

**Question 39 (23 marks)**

Catalytic converters are devices that significantly reduce the amount of pollutants released in the exhaust gases of vehicles. Government regulations in most countries generally state that all vehicles must be fitted with catalytic converters, with the aim of improving environmental and safety outcomes.

The structure of a catalytic converter is based on a honeycomb design, which has a very large surface area. This honeycomb structure is made of a ceramic material, which is coated with a mixture of alumina and silica. The rough surface of this coating further increases the surface area available for reaction.

The catalyst, which is a mixture of finely divided precious metals, is then embedded within this structure. Platinum is the most widely used catalyst, however palladium and rhodium are also very common.

(a) Explain, in terms of the collision theory, the function of a catalyst. (3 marks)

* **A catalyst provides an alternate reaction pathway with a lower activation energy.**
* **Therefore a greater proportion of particles can overcome the activation energy barrier / have collision energy greater than the activation energy**
* **This in turn increases the reaction rate**

Some of the reactions catalysed by the converter are given below.

1. 2 H2(g) + 2 NO(g) → 2 H2O(g) + N2(g) DH = -666 kJ mol-1
2. 2 CO(g) + O2(g) → 2 CO2(g) DH = -566 kJ mol-1
3. CH4(g) + 2 O2(g) → 2 H2O(g) + CO2(g) DH = -803 kJ mol-1

These reactions require a temperature of at least 425 °C to effectively convert the harmful compounds found in the exhaust gas. For this reason, the catalytic converter is located underneath the car, where the warmth from the engine provides the heat required.

(b) Explain how a high temperature increases reaction rate. (3 marks)

* **High temperature increases the average kinetic energy of particles**
* **This increases the frequency of collisions, and**
* **A greater proportion of particles can overcome the activation energy barrier / have collision energy greater than activation energy**

Analysis has shown that vehicles emit most of their pollution within the first 5 minutes of driving.

(c) Suggest a reason for this. (2 marks)

* **When the car is first started the engine is cold / not warmed up / below 425 °C**
* **Therefore the catalytic converter is not yet working at capacity**

(d) Sketch **one** labelled energy profile diagram that is representative of all three (3) reactions given on the previous page. Include on your diagram, the effect of the precious metals, such as platinum, used in the converter. (5 marks)

Ea

DH

Reactants

Products

catalysed pathway

Progress of reaction

Potential energy (kJ)

**(1) Exothermic shape of curve**

**(1) Reactants and products labelled**

**(1) Ea labelled**

**(1) DH labelled**

**(1) Catalyst pathway**

Catalytic poisoning occurs when substances such as lead, sulfur or manganese coat the inside surfaces of the converter. This significantly decreases the efficiency of the catalytic converter and allows most of the harmful exhaust gases to escape.

(e) Explain, in terms of the collision theory, the effect of catalytic poisoning on reaction rate. (3 marks)

* **Reduced surface area of catalyst available**
* **Therefore frequency of collision between reactants and catalyst would be decreased**
* **The reaction rate would thus be lower**

Catalytic converters function optimally when the exhaust gases passing through them are released from an engine where the oxygen to fuel ratio (oxygen : fuel) is kept slightly above stoichiometric point. For a petrol powered car, a ratio of around 14.6 : 1 is used.

The following equation is representative of the combustion reaction occurring in a petrol engine.

**2**  C8H18(l) + **25**  O2(g) → **16**  CO2(g) + **18**  H2O(g) + 10940 kJ

(f) Balance this equation and prove that the desired ratio of 14.6 : 1 is just above the stoichiometric point for this reaction. (3 marks)

* **(balancing shown above)**
* **oxygen:fuel ratio is 25:2 or 12.5:1**
* **Ratio of 14.6:1 is therefore just above the 12.5:1 stoichiometric point**

If the fuel tank of a particular vehicle carried 57.3 kg of petrol (C8H18);

(g) Calculate the total amount of heat energy produced if all the petrol in the tank was combusted. Give your answer to the appropriate number of significant figures. (4 marks)

**m(C8H18) = 57.3 x 103**

**= 57 300 g**

**n(C8H18) = m / M**

**= 57 300 / 114.224**

**= 501.6459 mol**

**Heat energy = 10940 / 2 x n(C8H18)**

**= 10940 / 2 x 501.6459**

**= 2 744 003 kJ**

**= 2.74 x 106 kJ (3 SF)**

**Question 40 (18 marks)**

Consider the reaction between hydrochloric acid and aqueous sodium sulfite, which is represented by the **unbalanced** chemical equation below.

\_\_\_\_ HCl(aq) + \_\_\_\_ Na2SO3(aq) → \_\_\_\_ NaCl(aq) + \_\_\_\_ SO2(g) + \_\_\_\_ H2O(l)

(a) Rewrite this molecular equation as a balanced ionic equation. (2 marks)

|  |
| --- |
| **2 H+(aq) + SO32-(aq) → SO2(g) + H2O(l)**  **(1m reactant and product species correct, 1m balancing)** |

(b) Draw the structural formula for each of the substances below. Represent all valence shell electron pairs either as : or – . (4 marks)

|  |  |
| --- | --- |
| Na2SO3 | 2 Na +  O S O  O  2-  **(1) 2 sodium ions**  **(1) sulfite ion**  **(1) square brackets and charges** |
| SO2 | O S  O  **(1)** |

Consider the five (5) compounds in the original molecular equation; HCl, Na2SO3, NaCl, SO2 and H2O.

(c) Classify each of these 5 compounds, according to the type of bonding present. (3 marks)

|  |  |  |
| --- | --- | --- |
| Ionic | Covalent | Ionic and covalent |
| **NaCl** | **HCl**  **SO2**  **H2O** | **Na2SO3** |

**(-1m per mistake)**

Select two (2) of the covalentcompounds that display **different** molecular shapes.

(d) Identify the shape of both your chosen compounds, and explain how the molecular shape of each can be predicted. (4 marks)

* **HCl is linear**
* **It has only one shared pair of electrons / It has only 2 atoms involved**

**EITHER**

* **SO2 is V-shaped / bent**
* **It has 2 bonding pairs and 1 non-bonding pair of electrons around the central atom**

**OR**

* **H2O is V-shaped / bent**
* **It has 2 bonding pairs and 2 non-bonding pairs of electrons around the central atom**

Both the NaCl and SO2 products are water-soluble.

(e) Explain, in terms of intermolecular forces, why each of these products is soluble in water. You may use labelled diagrams as part of your answer if you choose. (5 marks)

* **The ion-dipole forces that form between H2O and Na+ / Cl-**
* **Are large enough / Are sufficiently strong enough / Release a sufficient amount of energy in their formation**
* **To overcome the existing forces within the NaCl (ionic) and H2O (hydrogen, dipole-dipole and dispersion) and therefore dissolve**
* **The hydrogen bonding, dipole-dipole and dispersion forces that form between SO2 and H2O**
* **Are large enough / Are sufficiently strong enough / Release a sufficient amount of energy in their formation to overcome the existing forces within the SO2 (dipole-dipole and dispersion) and H2O (hydrogen, dipole-dipole and dispersion) and therefore dissolve**

End of questions